BBC RD 1976/17

BBC

RESEARCH DEPARTMENT

1969 1974
THE QUEEN'S AWARD TO INDUSTRY

REPORT

CEEFAX:
an investigation of interference from Teletext data signals into the sound circuits of domestic television receivers

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THE BRITISH BROADCASTING CORPORATION July 1976

CEEFAX: AN INVESTIGATION OF INTERFERENCE FROM TELETEXT DATA SIGNALS INTO THE SOUND CIRCUITS OF DOMESTIC TELEVISION RECEIVERS

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1. Introduction.

Complaints from viewers suffering from interference to the reception of the sound signals associated with the u.h.f. System I television transmissions, have revealed that teletext data, which is carried in the field blanking interval of the television signal, can cause interference to the sound signal. The interference, which normally appears as an impulsive buzz or "spitty" accompaniment to the sound programme, is thought to be experienced by only a small proportion of viewers* and appears to be confined largely to those with certain models of television receiver. As will be seen later, in all circumstances where "data buzz" occurred, "buzz-on-sound" interference brought about by certain types of picture information was much worse.

The tests described in this Report were intended, initially, to identify the types of distortion which cause "data buzz" interference and to try and locate the sources of the distortion. The tests were subsequently extended to include a survey of several domestic television receivers, so that their immunity to the interference could be assessed. For this purpose, a number of manufacturers supplied a selection of popular receivers on short-term loan. Some manufacturers also supplied extra receivers detuned to the limits of factory tolerance for use as "worst-case" examples for reference purposes. The co-operation of all the manufacturers involved was invaluable, and is gratefully acknowledged.

2. A probable mechanism for "data buzz" interference.

It is difficult to be precise about the processes which give rise to "data buzz" interference. As the video signal, including teletext, is filtered to remove frequencies above 5·5 MHz on System I transmissions, interference either into the broadcast f.m. sound signal or into the 6 MHz intercarrier sound circuits of the receiver must result from non-linear distortion. Furthermore, the level of interference has not been found to be affected appreciably by whether the teletext signal is passed through a 5·5 MHz or 4·5 MHz low-pass filter before combination with the television picture signal. Nor does the insertion of a 3 MHz band-stop filter into the output of the teletext generator appear to make any difference to the interference.

It is inferred therefore, that the "data buzz" interference is caused by intermodulation products of the form: $f_1 + f_2 + f_3 \ldots + f_n = 6$ MHz where f_1, f_2, etc., are the frequencies of various spectral components of the teletext signal. Although harmonic distortion undoubtedly contributes to "data buzz", the harmonic products (i.e. those for which $f_1 = f_2 = f_3 \ldots$ etc.) seem to be no more significant than any of the other intermodulation products, as is evident from the test for second-harmonic distortion using the 3 MHz band-stop filter.

3. Conditions under which the interference occurs.

Experiments, conducted to find the circumstances under which the interference was experienced, showed that "data buzz" did not depend on the level of signal at the input to the receiver. Two receivers of a type known to be particularly susceptible to the interference operated similarly in this respect with input signal levels ranging from 1 mV r.m.s. to more than 20 mV r.m.s. (at peak vision carrier). There were, however, two conditions of the received signal under both of which the interference from teletext was increased. These were, attenuation of the sound carrier, relative to the vision carrier, and increases in the modulation depth of the vision carrier by the teletext signal.

The peak vision-to-sound carrier ratio normally transmitted is 7 dB, and variations might occur under fault conditions or as a result of successive rebroadcasting of signals by a chain of relay stations. Overmodulation of the teletext signal might also occur under fault conditions. It is interesting to note that excessive overshoots on the teletext data pulses are sometimes broadcast (and rebroadcast), but these do not necessarily increase the interference. Overshoots caused purely by phase distortion have been found to be quite innocuous as far as interference is concerned (provided that they do not cause overmodulation of the transmitter) probably because phase distortion does not increase the signal power. If the overshoots are caused by amplitude/frequency response distortion, however, it is possible for interference to be increased. Fig. 1 shows the waveform of a normal

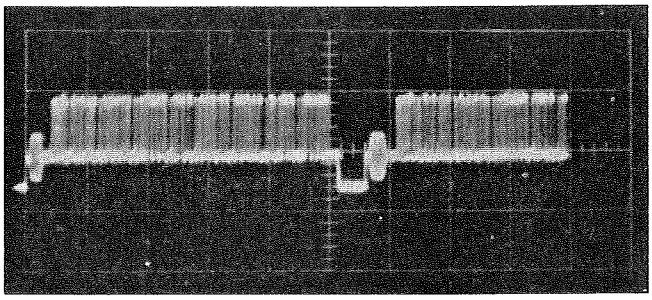

Fig. 1 - CEEFAX data signal with no distortion introduced

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* During the first eighteen months since CEEFAX was introduced, the BBC Engineering Information Department received about a hundred complaints from receivers suffering continuing interference. In addition, there have been one or two sporadic outbreaks of interference, but in most of these cases the duration of the interference was too short for any investigation to be made.

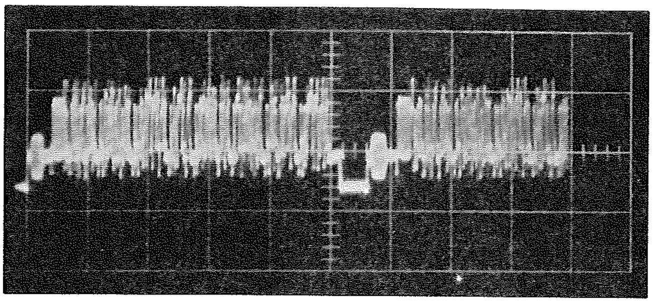

Fig. 2 - CEEFAX signal with phase distortion

CEEFAX data signal and the effect of phase distortion (introduced by passing the video signal through a group-delay distorting network) is shown in Fig. 2. No increase in "data buzz" occurred when the distorting network was introduced, despite the large overshoots on the waveform. However, when an amplitude equaliser giving 2 dB lift at colour subcarrier frequency and producing smaller overshoots was included in the path of the video signal (see Fig. 3) there was a significant increase in the level of "data buzz". The installation of data-regenerators in the network would be valuable in reducing overshoots which might prove troublesome, even though the principal function of these devices is to restore the eye-height of the data signal.

Quite apart from the possibility of the transmitted signal being impaired either from over-modulation by the data signal or because of too high a vision-to-sound carrier ratio, the received signal can suffer similar impairments as a result of multipath propagation. Partial cancellation of the sound signal will give an increased vision-to-sound ratio, whilst partial cancellation of the vision carrier relative to its sidebands will reproduce the overmodulation condition (in this case both the picture and the data signals will be overmodulated). From information obtained as a result of transmitter service area surveys and from brief expeditions into the field to investigate "data buzz", it appears that variations of up to ± 6 dB in the vision-to-sound ratio are quite common, and variations of ± 10 dB or more have been encountered. Propagation effects of this magnitude are quite sufficient to cause interference with receivers that are prone to the effect.

Reflections in the aerial feeder of a domestic receiving installation can also reproduce either an incorrect vision-to-sound carrier ratio or overmodulation. Multiple-outlet feeder arrangements can be particularly prone to trouble, and a significant number of cases with badly engineered multiple outlets have arisen in one area.

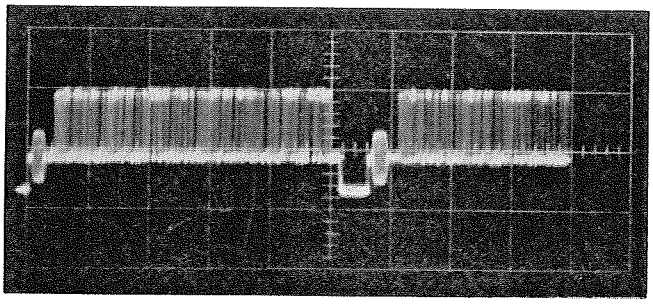

Fig. 3 - CEEFAX signal with amplitude/frequency response distortion giving 2 dB lift at colour subcarrier frequency

Multipath propagation and feeder reflections are far more likely than transmitter malfunction to produce the conditions in which "data buzz" is enhanced. In any case, transmitter faults are unlikely to last for very long, whereas impairments caused by multipath and feeder effects will be persistent. Whilst adjustments to the receiving installation (e.g. re-siting the aerial) can often effect an improvement, there will be situations in which some degree of multipath reception is unavoidable. It is therefore necessary that domestic receivers should be capable of operating satisfactorily in situations where the vision-to-sound ratio is enhanced or where partial cancellation of the vision carrier occurs.

4. Tests conducted on domestic receivers.

A number of domestic television receivers were tested for "data buzz" using the experimental arrangement shown in Fig. 4. Some of the receivers were taken at random from the manufacturers' production lines; others were detuned by the manufacturers, to be at the limits of the tolerance allowed on their specification in such a way as to be "worst cases" as far as the interference being studied was concerned.

In view of the tendency of some receivers to produce "caption buzz" or vision-on-sound interference with certain pictures, a signal corresponding to a very "quiet" picture* was used to modulate the System I television signal injected into the receivers. The level of sound carrier and the modulation depth of the CEEFAX signal were then adjusted so that the onset of "data buzz" could just be detected with no modulation of the sound carrier and with the receiver volume control set to give normal listening level. Graphs were then plotted showing the value of vision-to-sound carrier-level-ratio for a number of data signal levels, such that each receiver was operating at the "threshold" of the interference condition. The tests were conducted in this manner because the transition from silence to interference was found to occur quite abruptly with either an increase in modulation depth or a reduction of sound carrier, once this threshold had been reached. This means that results are more readily reproducible, and it was relatively easy to ensure that the receivers were all judged by the same standard, without recourse to an extensive series of subjective tests.

Results for the television receivers taken at random are shown in Fig. 5; those for the detuned receivers are shown in Fig. 6.

The effect of introducing an adjustable short-circuited stub of transmission line in parallel with the feeder to the

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* The picture was a colour slide of a soldier in a red tunic

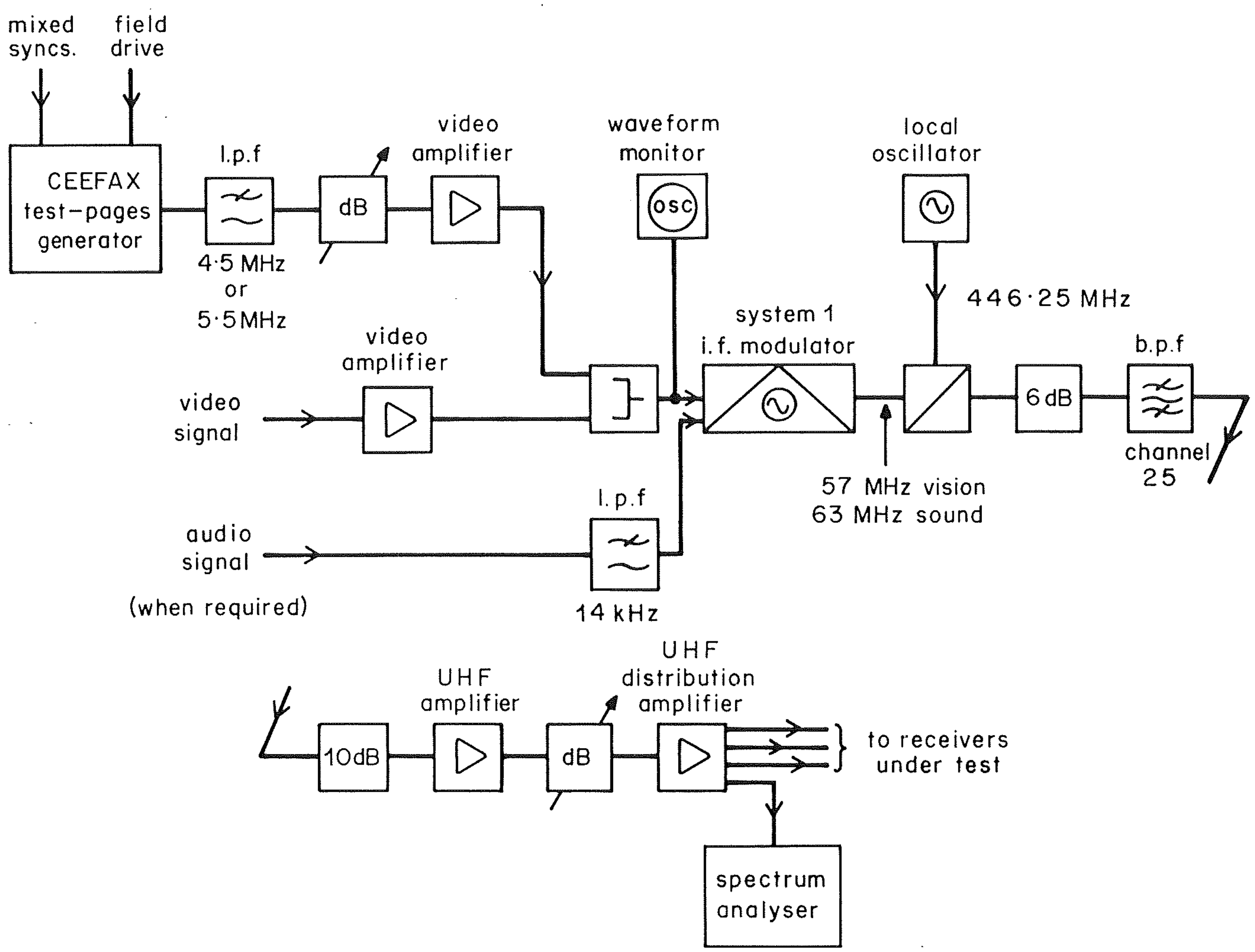

Fig. 4 - Experimental Arrangement

television receiver was investigated briefly. This technique produces cancellation of the signal at certain frequencies by introducing reflections into the feeder. Partial cancellation of the vision carrier (producing overmodulation) and partial cancellation of the sound carrier (giving a high vision-to-sound carrier ratio) both increased the level of "data buzz". The increase in the susceptibility of the receiver to interference, when the sound carrier was partly cancelled using the stub, was the same as that obtained when the sound carrier was similarly attenuated relative to the vision carrier in the previous tests.

The tests described so far have been relatively stringent, because a quiet sound channel was used. In practice, the sound channel rarely spends any appreciable time unmodulated during broadcasting hours. Subjective tests were therefore conducted, using one of the more vulnerable receivers, in order to establish subjective grades of impairment over a wide range of vision-to-sound ratios and data modulation depth for a typically "difficult" receiver. During these tests, the f.m. sound channel carried programme material (speech) at normal level. The results of the subjective tests are shown in Fig. 7. Impairment of the sound signal was assessed by 19 members of technical staff who awarded grades on the CCIR 5-point scale*.

5. Discussion of results.

The tests conducted on domestic receivers have shown quite a wide variation of susceptibility to interference from the teletext data signal between different models. It is interesting to note that some of the detuned receivers were less susceptible to the interference than receivers which had not had this attention; in fact, one particular "typical receiver" was worse than most of the detuned receivers. It was not a great deal less susceptible than a detuned version of the same chassis.

It became obvious during the tests that when a

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* The 5-point impairment scale contained in CCIR Report 623 (CCIR, XIIIth Plenary Assembly, Geneva 1974, Vol X) is as follows:

5 Imperceptible
3 Slightly annoying
1 Very annoying
4 Perceptible, but not annoying
2 Annoying

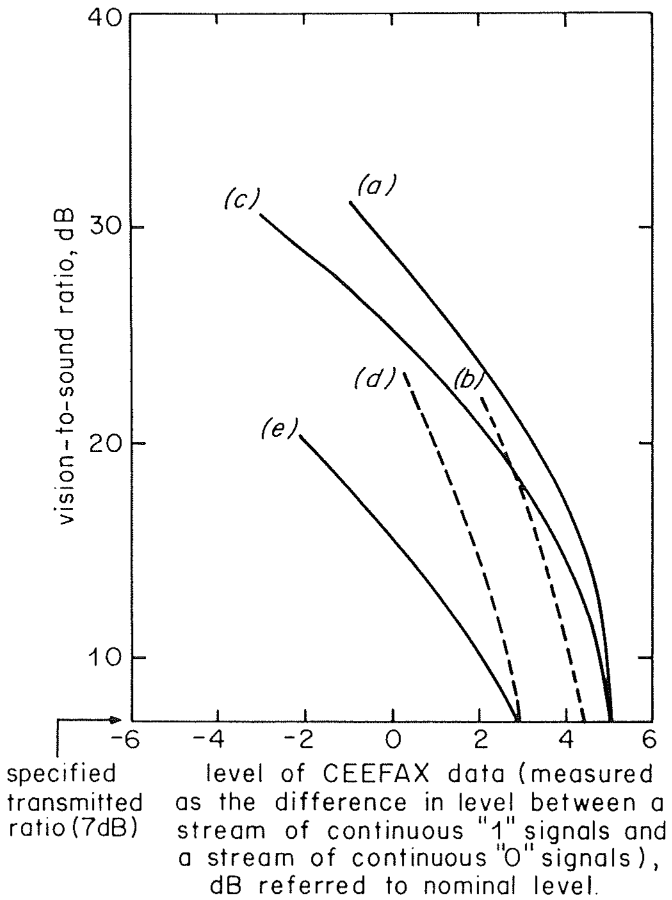

Fig. 5 - "Threshold of impairment" for receivers selected at random

________ colour receivers

_ _ _ _ _ monochrome receivers

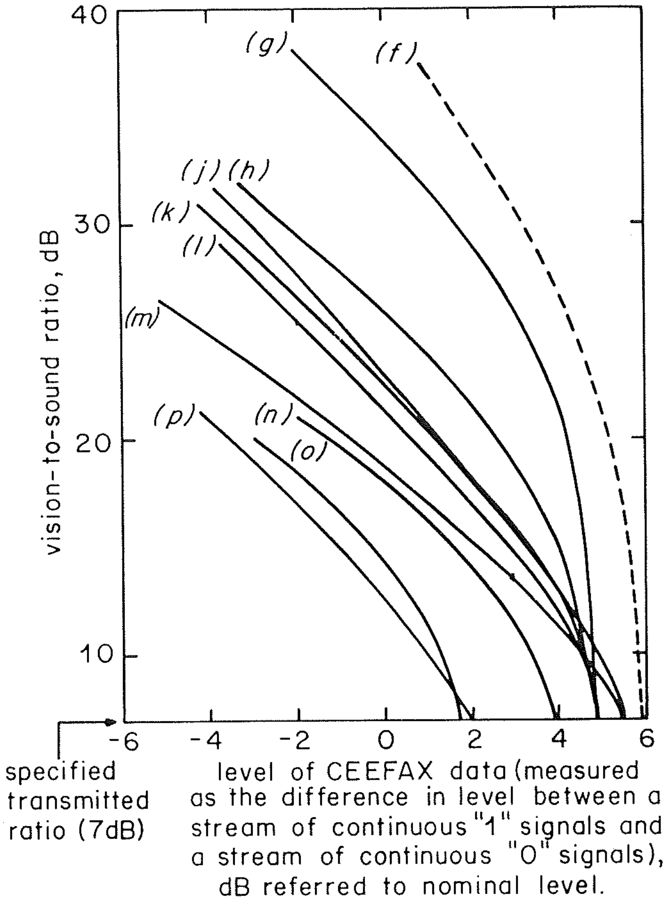

Fig. 6 - "Threshold of impairment" for factory detuned receivers

________ colour receivers

_ _ _ _ _ monochrome receivers

receiver suffered from "data buzz", it was possible to produce much more severe "buzz-on-sound" interference using pictures including captions or gratings (the SMPTE test card gave particularly severe interference). This applied whether the receiver was a "good" one (from the point of view that the sound channel was relatively insensitive to "data buzz") operating under extreme conditions, or a "poor" one operating close to the correct sound carrier level and modulation depth. It is clear, therefore, that a receiving installation which suffers interference from the data signal on the sound channel also suffers severe "picture buzz" from time to time.

There are probably two reasons why "picture buzz" complaints are more scarce. Firstly, pictures which cause interference occur only occasionally, the majority of pictures being "quiet". In the second place, viewers can see the data stream at the top of their received pictures if vertical deflection is insufficient. The simultaneous presentation of stimuli to the eye and ear can make it easy for the viewer to associate the buzz with the rhythmic changes in the data pattern. However, in one or two cases reported, the "buzz-on-sound" was, in fact, found to be caused by picture information and not the data signal.

As outlined in Section 2, it is most probably a non-linear process which causes data interference to sound reception. The most likely place for the non-linear distortion to occur appears to be the receiver itself, as some receivers have been found to tolerate quite extreme conditions of low sound carrier and overmodulation of the data whilst others are vulnerable to interference on near-perfect signals. With reference to Fig. 7, it can be seen that, for low data-signal modulation depths, the graphs have a slope of approximately 2; that is, a 2 dB change in sound carrier level compensates a 1 dB change in modulation depth. It seems likely that, in this particular receiver, the non-learity was such as to produce mainly second-order intermodulation products (i.e. those of the form $f_1 + f_2 = 6$ MHz) at low modulation depth. As modulation depth increases, so the graphs become steeper, implying increasing contributions from higher-order products. Most receivers gave curves of a similar form but, in one or two cases, the slopes of the curves differ quite considerably from those of the curves in Fig. 7. Particular samples are the curves for receiver b and d in Fig. 5.

It is now normal practice in domestic receivers for the i.f. sound signal to be derived as an "intercarrier" component (i.e. as a beat-frequency signal at 6 MHz formed from the received vision and sound carriers). The intercarrier sound signal can be obtained from the vision demodulator as a 6 MHz carrier which is combined with the video signal and careful filtering is necessary to separate the two. The problem with such an arrangement is that, in order to prevent the 6 MHz intercarrier sound signal and the 4·43 MHz chrominance signal from producing a 1·57 MHz "sound/chroma" beat pattern on the picture, the sound carrier has to be attenuated heavily (usually by about 30 dB) before the vision demodulator; because of the in-band frequency of the "sound/chroma" beat component, it cannot be separated from the video signal once it has been formed at the demodulator output. The attenuation of the sound carrier in the vision i.f. circuits greatly increases the vulnerability of the sound channel to interference from components of the vision signal (including the data signal). The solutions to this problem appear to be two-fold; either the intercarrier sound signal must be extracted from some point in the i.f. amplifier before it has suffered attenuation relative to the vision signal, or a vision demodulator with near-perfect linearity has to be used.

The use of simple diode envelope-demodulators in receivers has meant that the first of these techniques has been used to some extent in the past. However, synchronous demodulators have become available more recently, in the form of integrated circuits, and these offer the receiver manufacturer a very linear demodulator which is economical and capable of both demodulating the vision signal and producing a satisfactory intercarrier sound signal.

No detailed examination of receiver circuits was carried out during the work so it is not possible to give any definite indication in this Report as to the reasons why some receivers performed better than others. It is probable that the less satisfactory models used a common vision demodulator and sound intercarrier outlet in the i.f. circuit of the receiver. With such a system, and using an envelope-demodulator, it is likely to be very difficult to obtain a really satisfactory performance. There is no doubt that the use of a synchronous demodulator in this particular arrangement can give improved linearity and hence a much more satisfactory result, but it is important to ensure that the device used is operating in a linear fashion. This depends very considerably upon the design of other circuits which accompany it in the receiver.

6. Conclusions.

An investigation into the conditions which cause "data buzz" in domestic television receivers has been conducted. It is inferred that non-linearity in receivers, coupled with multipath propagation, are the principal causes of interference to sound from the teletext data signal, but that mismatching in receiving aerial feeders can also contribute to the problem. Domestic receivers have been found to vary widely in their susceptibility to the interference, and as it is impossible to eliminate multipath distortion completely in all cases, it is recommended that receiver manufacturers should try to meet certain minimum performance requirements in order to protect the sound channel from interference. It must be emphasised that it is necessary for these requirements to be met to eliminate even more severe interference to the sound channel from the picture information; the introduction of CEEFAX has not made the situation any more difficult, but merely drawn attention to the problem.

It is possible under certain conditions, for overshoots on the teletext waveform to aggravate the interference problem. The kind of overshoots which might prove troublesome are those caused by amplitude/frequency response distortion in the television distribution network. Overshoots due to phase distortion are more common but do not cause increased "data buzz". It is envisaged that data-regenerators will be installed at key points in the network to restore data eye-height; these will also remove excessive overshoots and thus reduce the likelihood of interference from this cause.

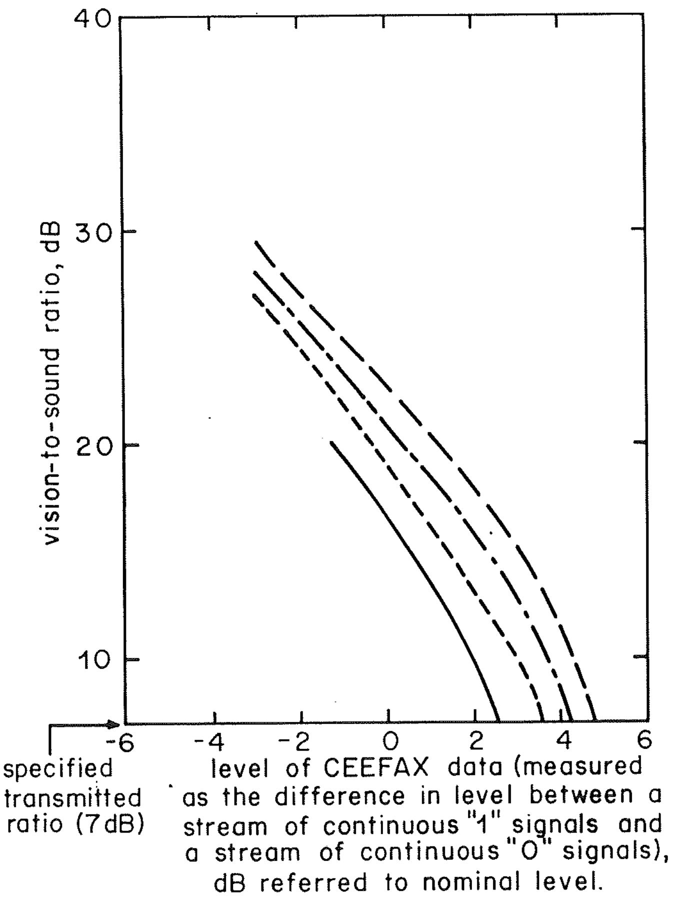

Fig. 7 - Results of subjective test to determine the variation of impairment to the sound signal over a wide range of vision-to-sound ratios and modulation depth using receiver (e).

———— grade 5)
– – – – – grade 4) subjective grades corresponding to CCIR
–·–·–·– grade 3) 5-point impairment scale (see Section 4)
— — — grade 2)

7. Recommendations.

Multipath propagation can disturb the vision-to-sound carrier ratio of u.h.f. television signals by ± 10 dB. It is therefore recommended that receivers should be designed to operate without any impairment due to "buzz-on-sound" when the vision-to-sound ratio is 12 dB too high (i.e. a vision-to-sound carrier ratio of 19 dB). There should also be no impairment when the modulation level of the data signal is raised to 3·5 dB above the nominal (0·5 volt peak-to-peak added to a 1 volt video signal); this should ensure adequate protection when cancellation of the vision carrier occurs.

Subjective tests show that a receiver meeting these requirements will begin to show slight disturbance of a sound signal carrying normal programme material when the vision-to-sound ratio is 14 dB too high and the impairment will be only grade 4 on the 5-point scale (see Section 4), which is "perceptible but not annoying", when the vision-to-sound ratio is 17 dB too high; such instances are very rare.

It is to the credit of receiver manufacturers that the majority of television sets submitted for test fulfilled the requirements proposed in this report. Of those which did not meet the requirements, most did not fall very far short of the recommended performance. It is, however, from owners and operators of many of these receivers that most of the reports of "data buzz" have been received.

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Printed by BBC RESEARCH DEPARTMENT, Kingswood Warren, Tadworth, Surrey, KT20 6NP